HYDROLOGIC PREDICTABILITY OVER THE UNITED STATES

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Questions?

- Are we able to identify regimes that SM and runoff forecasts have high skill and understand the physical mechanisms behind the predictability?

- Do the Multi Model Ensemble (NMME) forecasts of Soil moisture (SM) and Runoff have better skill than individual models if all hydroclimate forecasts are initialized with the same initial conditions?

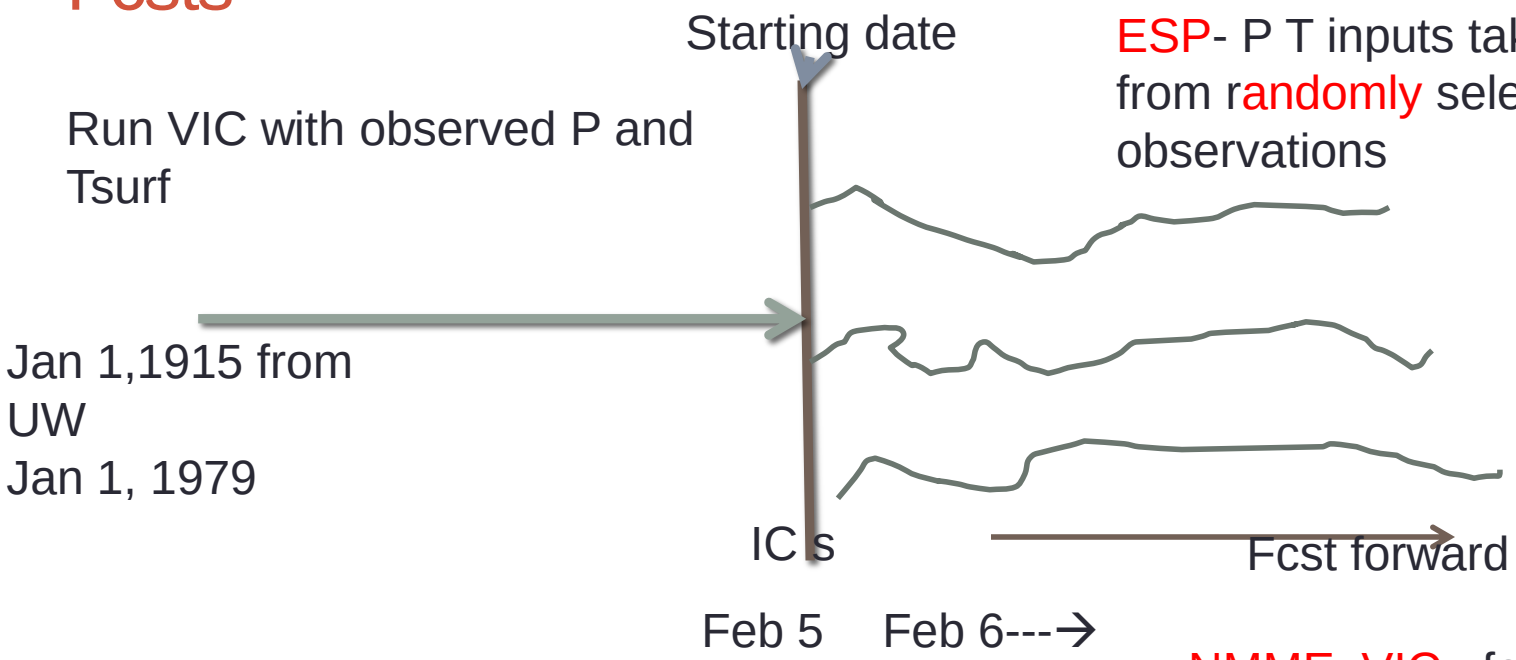
National Multi-Model Ensemble (NMME)

- 6 models
- Cfsv2– 16 members
- GFDL,CMC1,CMC2,NASA – 10 members
- NCAR– 6 members

VIC(SIM)

- We ran VIC driven by observed forcing from Jan 1, 1979- 31 Dec 2010 with ICs from 31Dec 1978. We label that run as the VIC simulation VIC(SIM).
- It was used for verification and the initial conditions for NMME_VIC and ESP
- Another VIC run from 1916 to 2011 for diagnostics

ESP (Ensemble streamflow prediction) vs NMME_VIC Fcsts



ESP- P T inputs taken from randomly selected observations

NMME_VIC :forcings were taken from error corrected T P from members of the NMME

Both ESP and NMME_VIC have the same initial conditions, but ESP has no climate forecast information of P and Tsurf

NMME_VIC forecasts

- For each CGCM model, each member ==>
- Initial conditions --taken from VIC(SIM)
- Climate forcing ----derived from error corrected P and Tsurf monthly mean forecasts for that member (Wood and Lettenmaier 2006)
- Drive VIC to get SM and Runoff
- For a given target year and given model, the ensemble mean is the equally weighted mean of all members. The climatology of the forecasts is corrected by using hindcasts except the target year.
- The grand ensemble mean is the mean of error corrected outputs of 6 models
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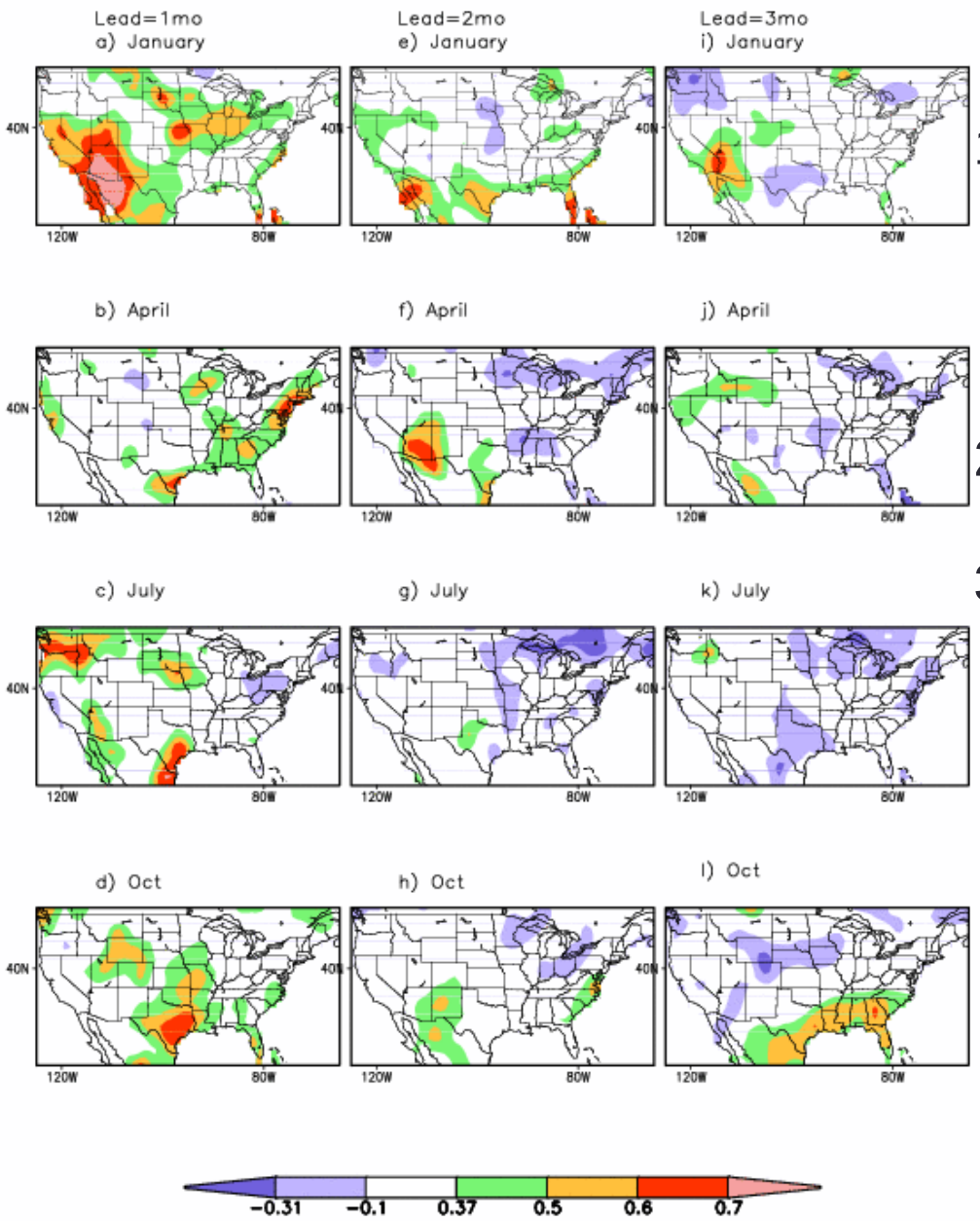
Verification

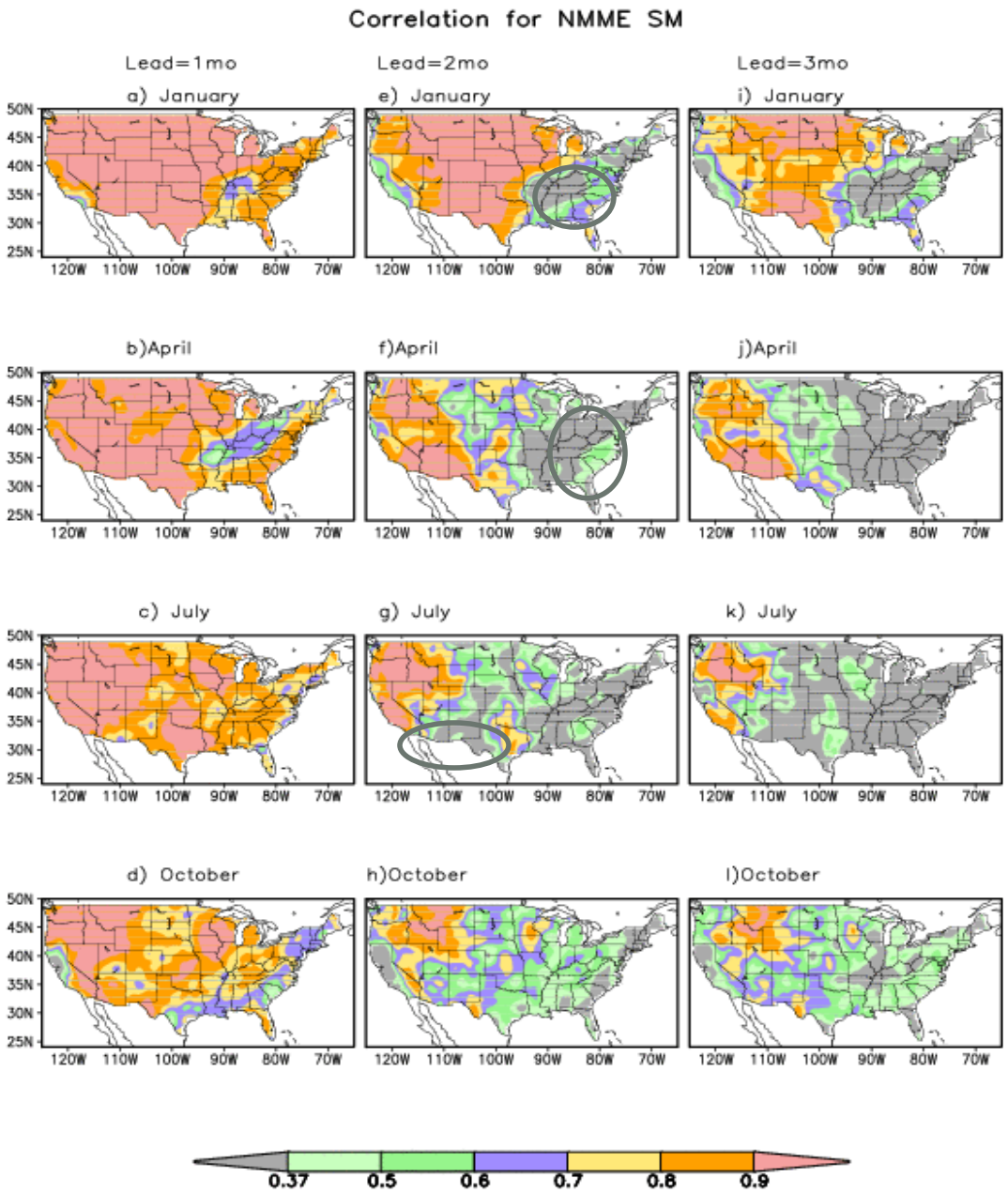
- Against VC(SIM)
- Pearson correlation --- with 29 dof, the correlation > 0.37 to be statistically significant at the 5% level
- The difference of correlation bw NMME and ESP is assessed by using the Fisher's Z transformation
- e.g. if R1=0.8 then R2 needs to be less than 0.55 to be statistically significant at the 5% level
- Field significance is assessed by using the Livezey and Chen (1983)

FCST skill for P



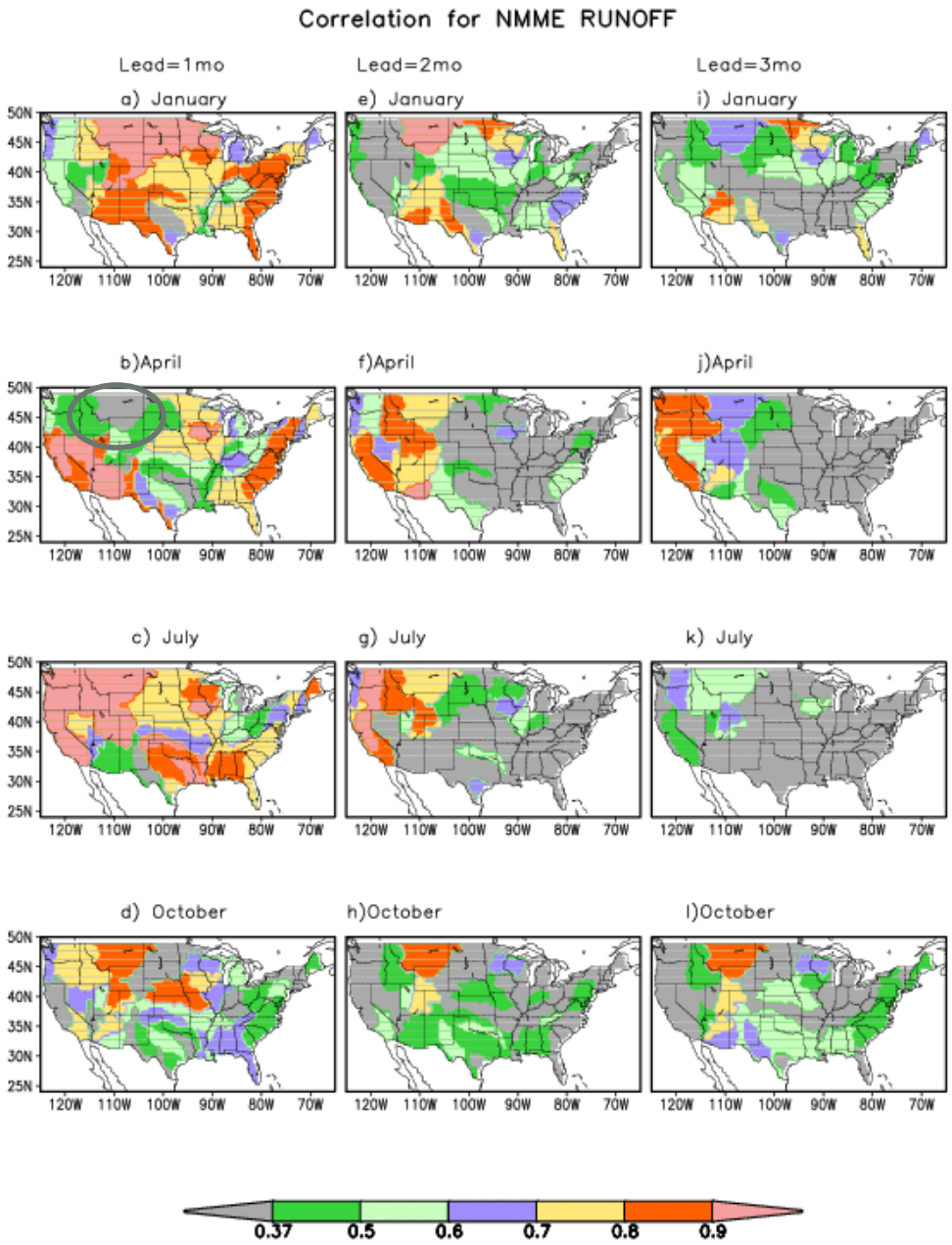
1. For lead_1 mo, forecasts, the mean anomaly correlation is 0.4 for winter and 0.34 for summer.
2. The skill drops sharply after lead 1 month
3. At lead-3 mos, only October forecast shows and passes the field test. It shows skill over the southern U.S.

Areas with negative skill are colored purple.



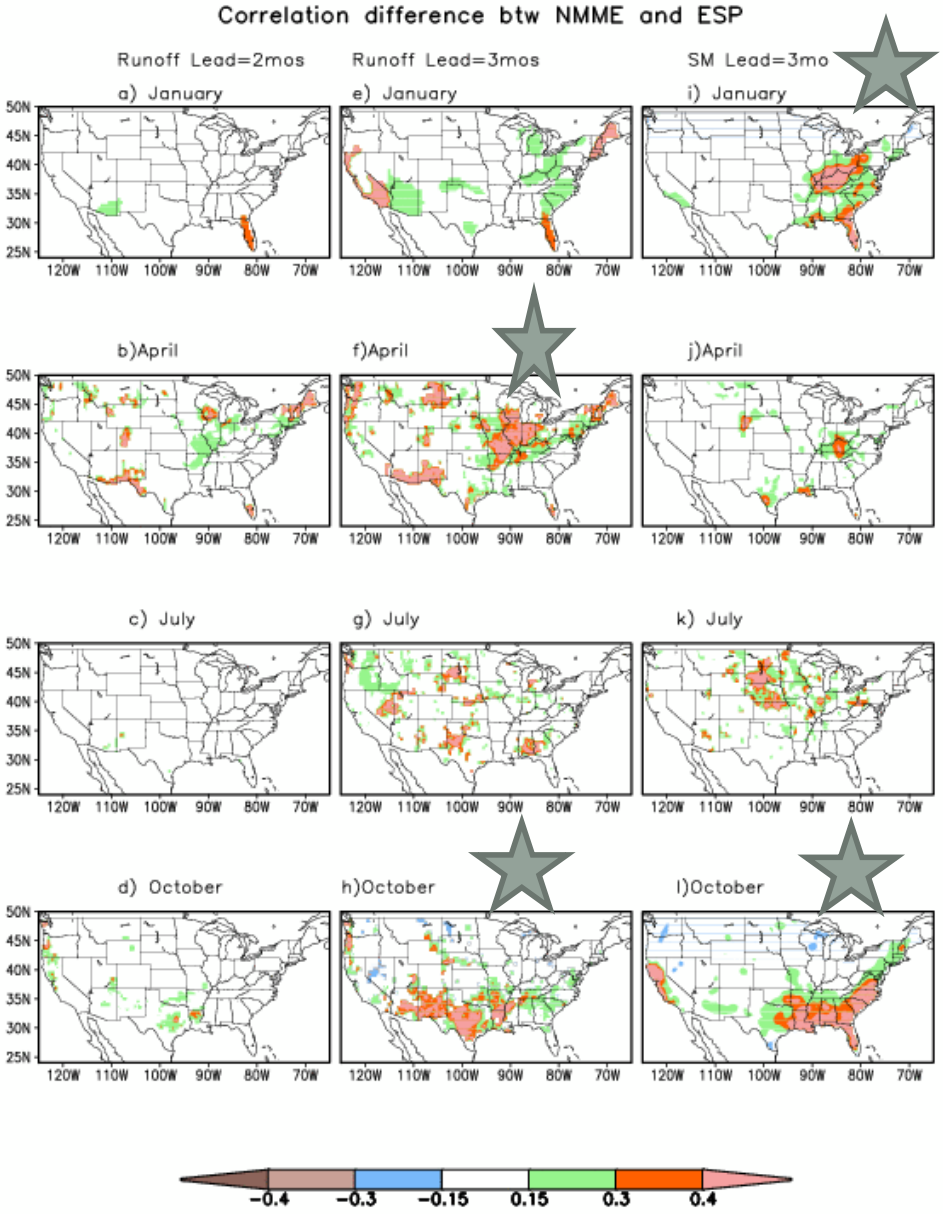
Fcst skill for SM

- Lead-1 : correlation >0.8
- Strong west-east contrast
- high skill areas:
  - Over the western interior dry region, the fcsts are skillful for all seasons
  - the North Central and the Southwest for January at Lead-3
- Low skill areas:
  - Eastern U.S except the coaster areas.: after lead-1 for all seasons
  - North American monsoon areas : July
  - Tennessee and Ohio Valleys in Jan and April : dynamical active areas



Fcst skill for Runoff

1. Strong west-east contrast
2. Areas that the sm has high skill also have high runoff skill
3. Runoff has overall lower skill in comparison to sm
4. For the Missouri basin the forecast of the SWE influences the forecast skill of RO



Compare with the ESP

1. No statistically significant differences at lead-1 mo.
2. At lead-2 there are differences at isolated places but maps do not pass the field test.
3. At lead-3, NMME is superior for

- October forecasts for SM and RO
- January SM forecasts over the Coaster areas and the Tennessee & Ohio Valleys
- April runoff forecasts over the North Central
- Others do not pass the field test
- Improvements are located in the low skill areas

Two hydroclimate regimes over the United States.

1. Dry regime with high forecast skill

- Areas include
  - the western United States for all seasons and the North Central and the Southwest for winter

Forecast Features are

- Forecasts of SM and RO have high skill even at Lead-3
- Skill is dominated by the initial conditions
- The ESP can be equally skillful

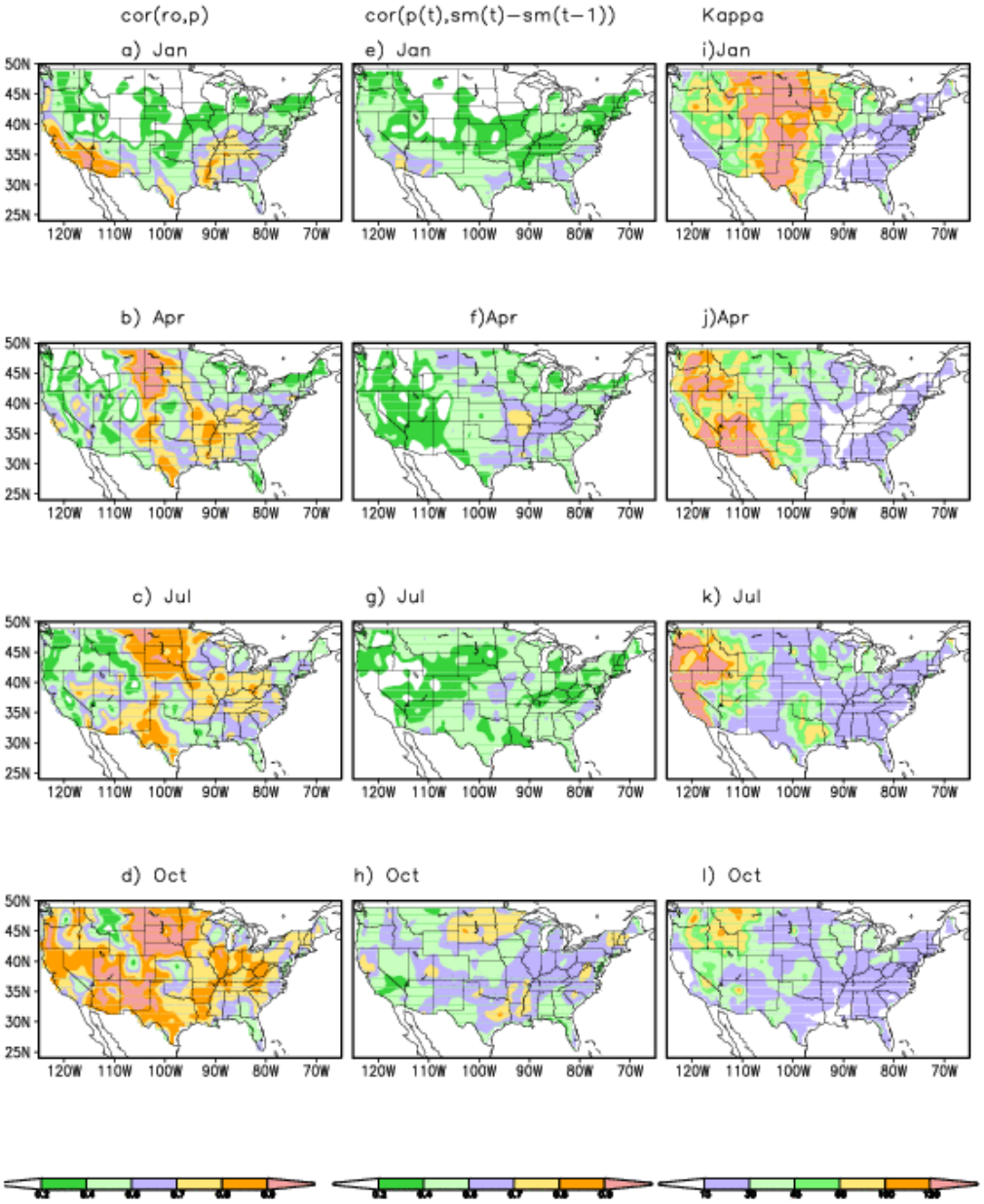
2. Wet regime with low forecast skill

Areas include

- The eastern United States, a path from the Gulf of Mexico to the Tennessee and Ohio Valleys and the monsoon areas

Forecast Features are

- Skill is low even at lead-1
- Skill comes from the NMME forecasts (atmospheric forcing)
- The NMME is better than ESP if P forecasts are skillful



correlations

1. **P has little influence on SM and runoff over the North Central and the western region –persistence of IC s dominants**
2. **P has less influence on ro and sm over the western than eastern U.S.- west-east contrast**
3. **P has strong influence on runoff and SM for Oct**
4. **IC s has larger influence on SM fcst skill than Ro because**

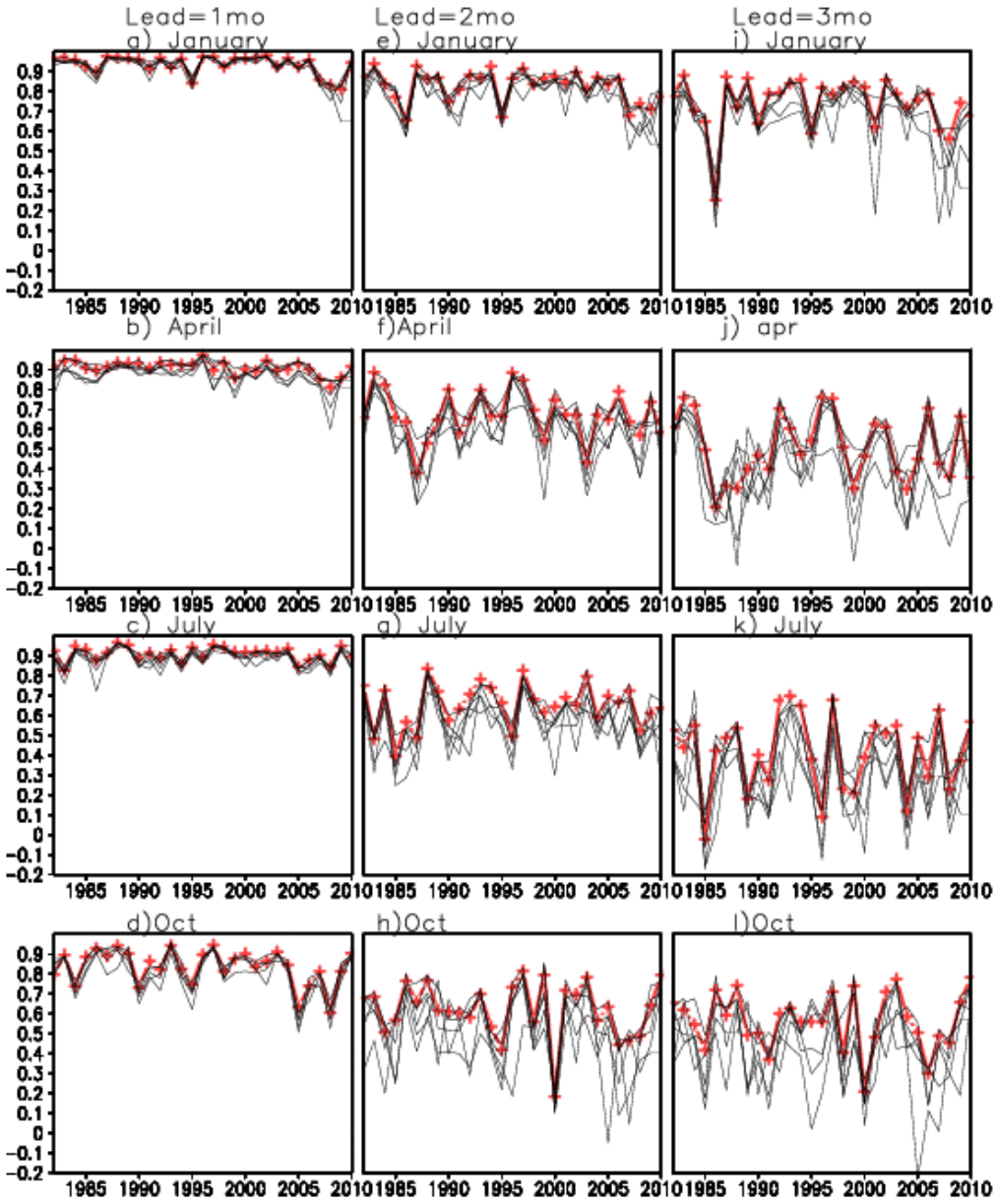
SM(t)=SM(t-1)+cor* P+ ε

And smaller cor

5. **Kappa=var(sm)/var(p)**

Data from VIC (SIM) from 1916-2010

Anomaly correlation coefficient for SM



Does the ensemble mean have higher skill?

Red– ensemble mean
Black– 6 models

- At Lead-1, Acc is high and spread is low
- At Lead-3, spread increases as skill decreases –could be that all run has the same IC s
- Skill for the ensemble mean is comparable to the skill of the best model

Two hydroclimate regimes over the United States.

1. Dry regime with high forecast skill

- Forecasts of SM and RO have high skill even at Lead-3
- Low spread among members of ensemble
- Skill is dominated by the initial conditions
- The ESP can be equally skillful
- Correlation with P is small
- Large Kappa --- small P climatology < 1.5 mm/day and small P variability

2. Wet regime with low forecast skill

- Dynamically active regime . If P fcsts are skillful, then the SM and Ro forecasts will improve.
- Forecasts of SM and RO have low skill even at Lead-1
- High spread among members of ensemble
- Correlation with P is high – influenced by P fcst skill
- Small Kappa ---wet P climatology and large P

Challenges

For dry regime

- The forecast skill is dominated by the initial conditions. Usually, the IC s are taken from the NLDAS
- To improve SM and Runoff forecasts, we need to improve NLDAS. That implies to improve P analysis and on time reporting of station data.

For wet regime,

- The forecast skill is controlled by climate forcing;
- To improve P forecasts will improve SM and Runoff forecasts.

Conclusions

- GIVE Me :

  Better P forecasts at Lead-2 and Lead-3

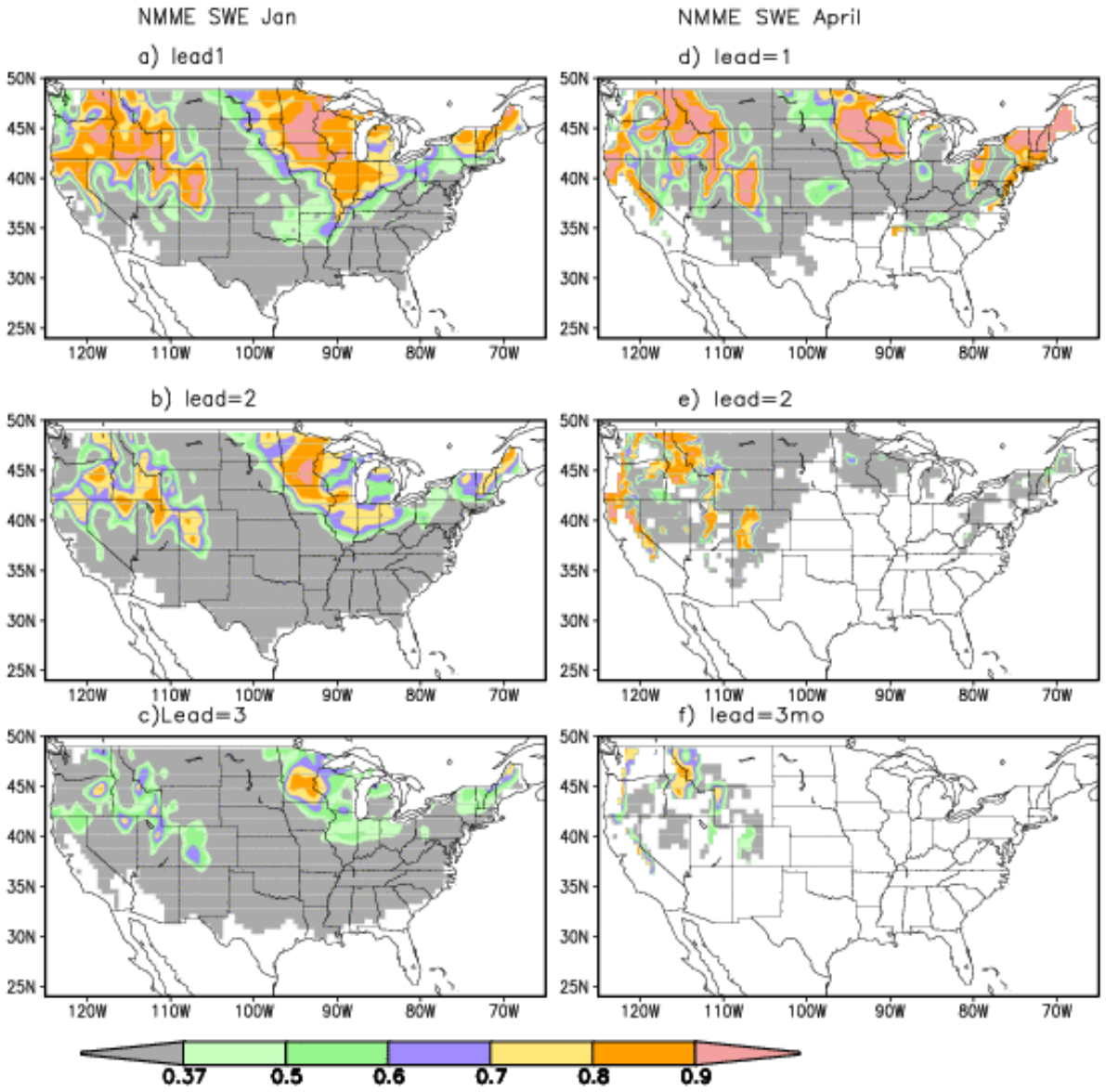
  You will have

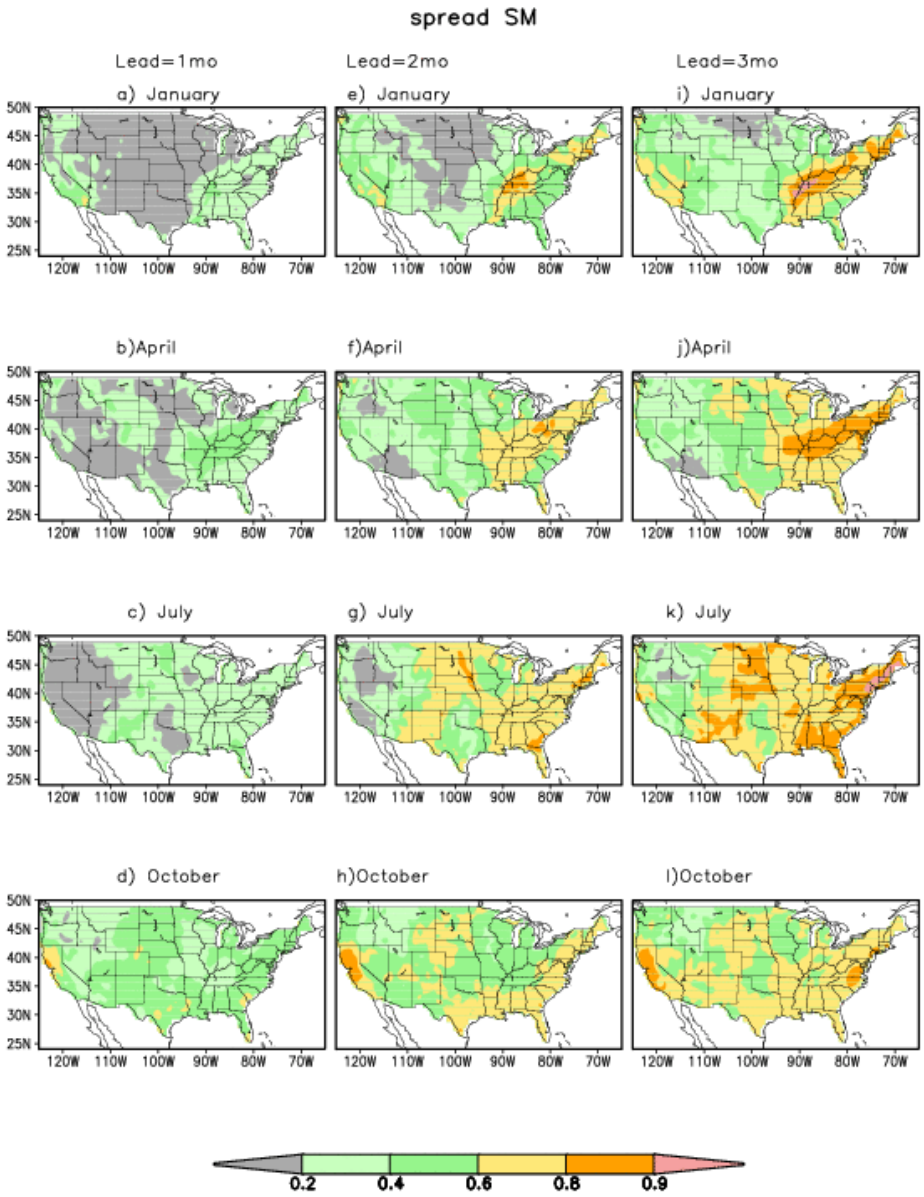
  Better SM and Runoff forecasts over the dynamically active region

- Give me

  better station data reporting in real time and better P analysis

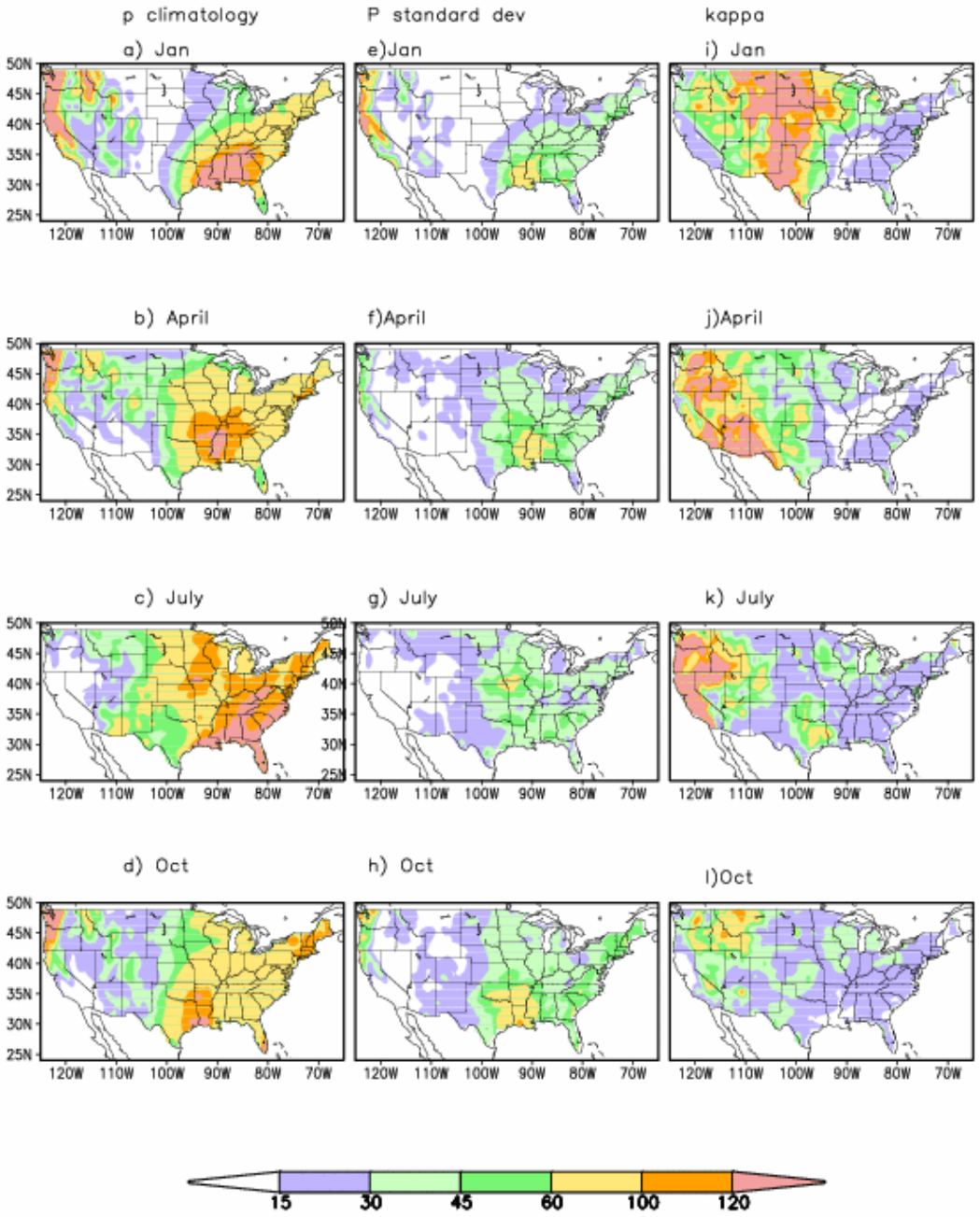
  You will get : better NLDAS with less uncertainties and better forecasts over the dry areas


NMME SWE Jan
a) lead1
b) lead=2
c)Lead=3
NMME SWE April
d) lead=1
e) lead=2
f) lead=3mo
50N
45N
40N
35N
30N
25N
120W
110W
100W
90W
80W
70W
0.37
0.5
0.6
0.7
0.8
0.9



Spatial structure of the spread

- The spread for Lead-1 is very small because they are dominated by initial conditions which are the same for all models
- The pattern of spread appears early at lead-1 and then the magnitudes increases as the lead increases
- Large spreads are located in the areas with low skill. Those are dynamically active areas. The CF controls rainfall

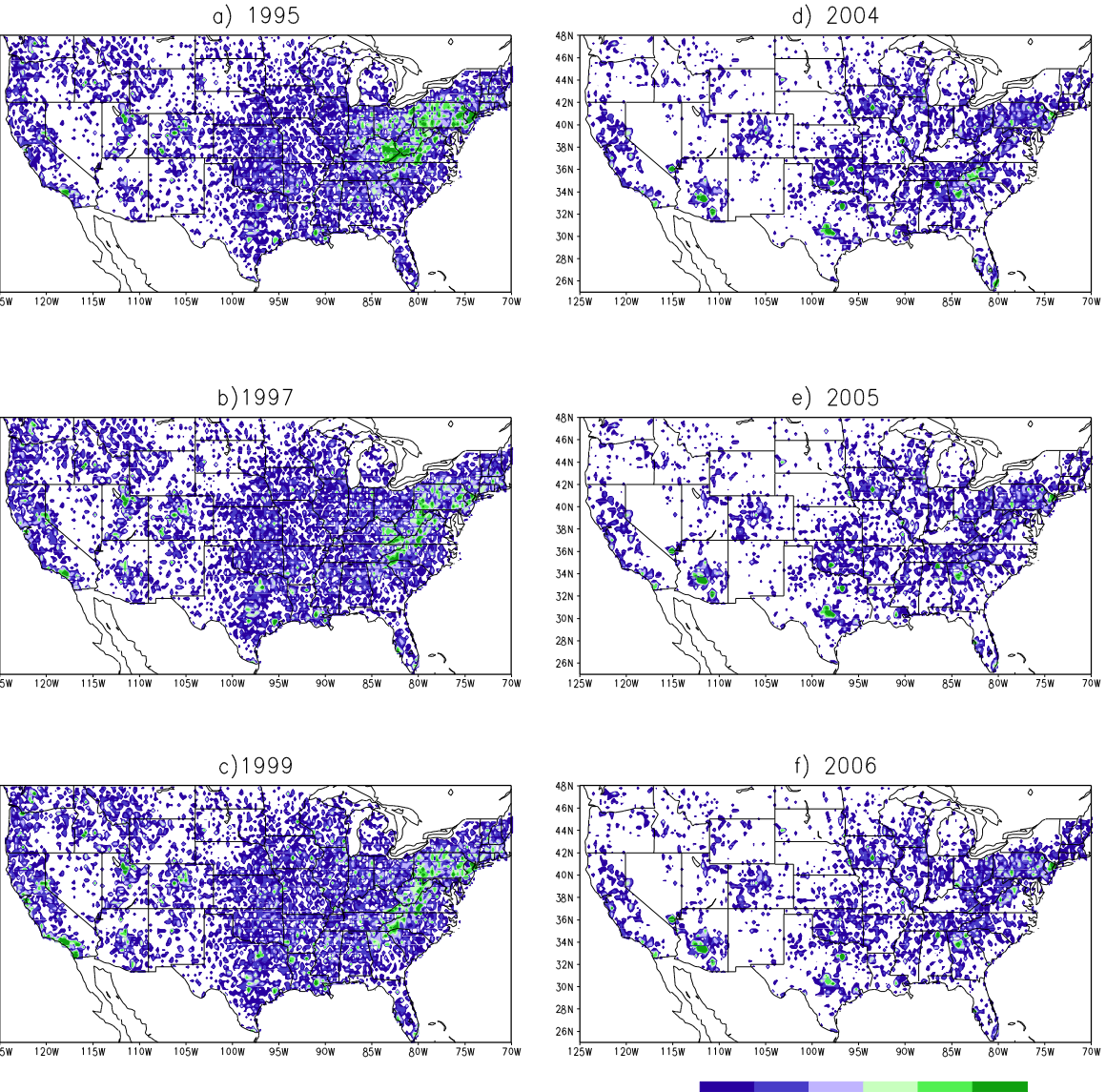


The climatlogic features

1. the high skill areas are
   - Dry with mean rainfall less than 0.5-1 mm/day
   - It has low standard deviation for P
   - Areas with large kappa
2. The low skill areas are
   - Wet with large P variability and small SM variability
   - Rainfall is determined by moisture flux convergence
   - Small Kappa= var(sm)/var(p)

Historical period

Real time period



Number of station reports averaged over a year

In real time, the station reports dropped over the western interior region

⇒ lead to large uncertainties in the NLDAS

⇒ uncertainties in the initial conditions for the fcsts

⇒ lower skill